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FS-INT-1202-448 May 1969

HEIGHT GROWTH OF PONDEROSA PINE IN THE TOWN CREEK PLANTATION

FINAL REPORT

BY
Dale O. Hall

INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION
Boise, Idaho

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ABSTRACT

In 1954 ponderosa pine planting studies were initiated at Town Creek (Boise N. F.) to test 3 site preparations--(1) no treatment, (2) stripped, and (3) stripped and furrowed--and 3 planting stock treatments--(a) 2-1 stock transported and handled conventionally and planted by the slit method; (b) 2-1 stock given special handling and planted by the dug-hole method; and (c) 2-0 stock given the same special handling and planting. The 9 treatments were applied for 5 years, 1954-1958. Survival results were published by Curtis and Coonrod in 1960.

In 1959 height differences on the 9 treatments suggested this as a new study phase. By 1968, 2-, 5- and 10-year height measurements were completed. Average heights of sampled trees followed closely the survival results for the treatments. These heights (feet) at 10 years by site preparation were: (1) 3.18, (2) 5.06, and (3) 5.05. For planting stock treatments the mean heights were: (a) 4.19, (b) 4.88, and (c) 4.28. Brush removal is essential for acceptable survival and height growth. The planting stock handled and planted carefully grew taller.

An unexpected relationship developed when age, height, and survival percents were graphed. Extrapolation of the regression surface to the boundary, at 100 percent survival, holds some promise as an absolute measure of height growth potential.

Trees planted in the rows next to cut banks grew taller than trees in the outside row (8.56 feet vs. 8.19 feet at 12 years).

Soil, climate, vegetation, animals and insects add some random differences to the heights attained.

Trees planted in brush were shorter than adjacent trees on stripped ground. This implies possible errors in site index evaluation based on total age. Some improvement results of site curves and estimates are based on age at breast height.

Economic comparisons showed a lowest cost per 100 live seedlings per acre with the stripped and furrowed site preparation and 2-1 planting stock handled conventionally. The high cost of the dug-hole planting method accounted for this apparent inconsistency.

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INTRODUCTION

In March 1954, the Town Creek ponderosa pine planting study was proposed by Lester Moncrief, Assistant Regional Forester, R-4 Timber Management.[1/] In cooperation with Research and the Boise National Forest a meeting was held and the many variables were discussed. It was decided that this study would start at the nursery. The 2-1 and 2-0 stock would both be handled under a careful regime to minimize shock in lifting, bundling, storage and transportation. The dug-hole planting method was to be used. Some 2-1 stock would be handled in the regular way and planted by the slit method as a check. Site preparation tests consisted of: no treatment, brush stripping and brush stripping with furrows. The tests of the 3 planting stock x 3 site preparation treatments were to run for 5 years (1954-1958) with tree survival as the evaluation criteria. All operational aspects were controlled by Region 4 Timber Management. Research prescribed the experimental design, established grading and planting procedures, and assisted in training the tree planters in the care and planting of ponderosa pine.

Survival results for 1, 2, and 5 years were published in 1960 (Curtis and Coonrod).

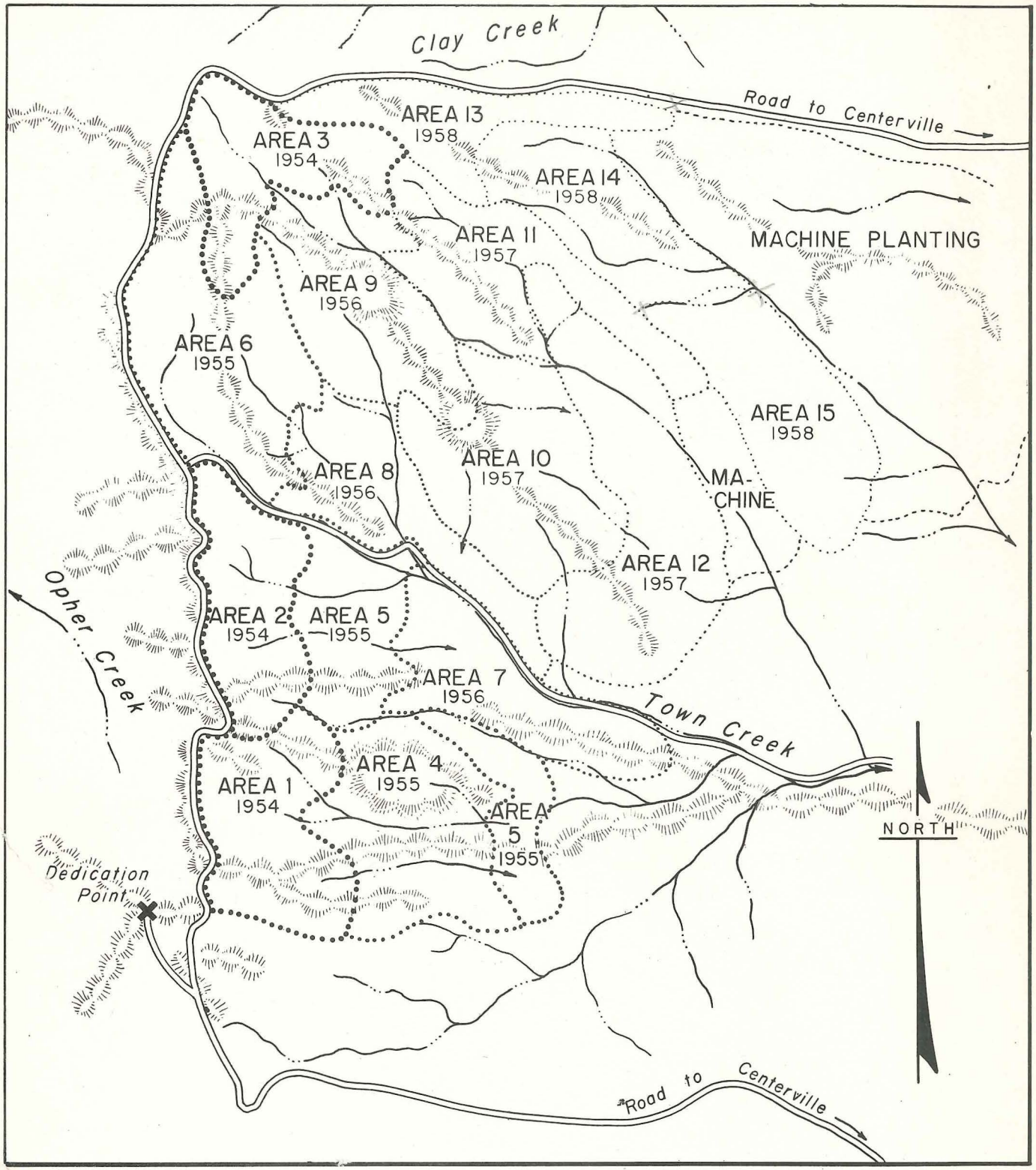
1/ Anonymous. Town Creek planting study. 25 pp., illus. 1954. (Unpublished report on file in Regional Office (R-4) U.S.D.A. Forest Serv., Ogden, Utah.)

In 1958 the differences in heights of trees on adjacent treatments suggested that treatment differences did exist. In 1959 this height growth phase, to evaluate the magnitude of treatment differences, was initiated by Jim Curtis with Marvin Foiles' assistance. This is the final report on this height growth phase.

STUDY FRAMEWORK

Planting layout.--In each of 5 years - 1954 to 1958 - 3 areas were planted at Town Creek (Fig. 1, Areas 1-15). The 3 areas were not mutually contiguous. Each area was subdivided into 3 sections. In the survival analysis only these 3 sections served as replications. Within each section one or more sets of 9 parallel strips of ground, about 8 to 12 feet wide, were designated for treatment. These strips ran for many 100's of feet in each section crossing a number of slope-aspect combinations. The 9 treatments were the 3x3 set of site preparation-planting stock comparisons randomly assigned to the parallel strips. Seedlings were planted in 2 rows on the strips. The rows were 4 feet apart with trees 6 feet apart in the rows.

Figure 1.--Map of Town Creek Planting Study.



U. S. FOREST SERVICE

BOISE NATIONAL FOREST

TOWN CREEK PLANTING STUDY

DPS, Ogden, Utah

Height measurements.--In July 1959, 2-year height measurements were made on 15 trees from each of the 9 treatments on 2 aspects[2/] for each of 5 years (1954-1958) of plantings (tables 1, 2). Five-year heights were measured on the 1954 and 1955 areas using different trees. I could find no notes on how any of these 15 trees were selected. Apparently, in each year's planting, without regard for areas or sections used in the survival study, two aspect locations were selected which had "uniform soil depth and slope" (Tab. 2). The heights were then measured along the treatment strips on these aspects.

Based on the 1959 field notes it appears that 15 trees were not always available from one aspect location. Secondary aspect locations were occasionally sampled (Tab. 1). I suspect that it was sometimes difficult to find 15 trees on the "no treatment" strips. The notes suggest that the same number of trees were measured for each treatment at each secondary aspect location. I find no evidence that the 3 sections of each area or the 3 areas of each year's plantings were sampled independently, nor that any of the height measurement trees were marked for future recovery. This is appropriate for if this series analysis is to be used each sampling of the universe should be randomized.

[2/] Aspects were added to the study between April and July 1959. Marvin Foiles has suggested the aspect subdivision stemmed from differences found in natural seedling studies at Boise Basin Experimental Forest and that the 2 aspects should center on SW and NE.

Table 1.--Location of height measurement trees, Town Creek

Year planted	2-year growth			5-year growth			10-year growth		
	Area	Sec.	Aspect	Area	Sec.	Aspect	Area	Sec.	Aspect
1954	2	1	E(N60E)	1	1&2	S	1	1	W(S30W)
	3	3	W(S20W)	2	1	NE&E	2	1	E(S40E)
1955	5	1&2	W(S74W)	6	3	W(S25W)	4	1	E(N70E)
	5	3	E(N80E)	6	3	E	6	3	W(S90W)
1956	7	3	E(N75E)				8	1	E(S70E)
	8	3	W(S87W)				8	3	W(N60W)
1957	11	1	E				11	2	W(S75W)
	11	2	W(S8W)				11	2	E(S70E)
	12	1	W						
1958	13	1	E(N80E)				13	2	W(S70W)
	13	1	W(S12W)				14	1	E(S90E)

Table 2.--Instructions for Town Creek height measurements - 1959

1. Measure 15 trees in each category (variable combination) growing on sites judged uniform in soil depth and slope.
2. Measure total heights (in tenths of feet) of first 5 years' growth (after planting) on 1954 and 1955 plantings.
3. Measure first 2 years' growth (after planting) on 1954, 1955, 1956, 1957, and 1958 plantings (in tenths of feet).
4. In recording growth use separate columns for free to grow and suppressed.
5. Make up 4- and 6-foot sticks marked in tenths of feet.

Weather is ignored: criterion is - height of average tree n years after planting.

This will provide growth expressions for:

1. Five years of growth for plantings in 2 years 1954, 1955 for each of nine variable combinations
2. Two years of growth for plantings in all 5 years for each of nine variable combinations.

In 1968 Gary Baertsch and I measured heights again on areas selected that year (Table 1). An appropriate aspect of sufficient extent would be located and scanned for evidence of pronounced height difference trends or highly variable heights for which we could readily identify causes. If no reason was found to bypass the location, a convenient point was selected toward one end and a starting line, which crossed all 9 treatments, was marked with plastic flagging. Working from this line, along the first treatment strip, trees were systematically selected, i.e. every other, every third, etc., in alternate rows across the slope. The systematic spacing was intended to spread the sample across the full extent of the slope and therefore was varied with each treatment strip according to the approximate number of trees surviving on that strip.

Tree heights were measured in feet and tenths from a Philadelphia rod beside the stem and placed at mean ground level. Annual heights for 1963 to 1968 were recorded in an ADP format using the top of each whorl as the best indicator of past height. All measurements were taken before there was a full realization of analysis problems.

Height measurements took 10 man-days, including daily travel from Boise. It snowed on several days.

Data processing.--The 1968 measurements were recorded on a form adapted for ADP use (App. A and B). I transcribed the 1959 measurements to the same form. ADP cards were punched and verified by the Boise State College ADP Center under a blanket purchase order.

I wrote an ADP summary program in Fortran IV for the IBM 1130 to develop means, S.D., and ranges for each group of 15 trees (App. C). A second program, in 4 parts, (App. D) developed the analysis of variance.

FACTORS INFLUENCING EARLY HEIGHT GROWTH

Juvenile height growth of individual trees may be influenced by the applied treatments and by numerous constant and randomly occurring environmental factors. The "constant" site factors would include latitude and longitude, slope, aspect, soil depth, and elevation. The primary tree constant is its genetic character. Some of the anticipated random events are insect attack, random fertilization by mammals, the annual weather, vegetative competition, and planter handling and placement. The heights for each treatment and year of planting 2 and 5 years after planting were the original variables to be analyzed. I will also touch on some observed factors as a matter of record.

APPLIED TREATMENTS

The proposed analysis of treatment differences presented some specific unresolvable problems. Correspondence in 1966 between Curtis and Carter (formerly Station Statistician) suggested a reconsideration of Curtis' experimental design. Apparently Curtis intended using the same experimental design applied to the survival study. The mean height at 2 and 5 years for the 9 treatments seemed to be the objective in April 1959 (table 2). By July, when field measurements were made, a test of 2 aspects had been superimposed.

The fact that the 2 aspects selected were in different sections and/or areas suggests that area differences could overshadow aspect

differences. This failure to randomize the aspect selection[3/] and to

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[3/] All acceptable aspects in an area could have been identified (numbered) and then one or more randomly selected for measurement.

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replicate the annual treatments has invalidated the design. Any test of aspects would rest on the hazardous assumption that there were no site differences between sections and/or areas. I am unwilling to make this assumption. In spite of this problem there is fairly strong evidence to support an analysis of height differences between treatments (as opposed to height potentials). The fact that: the 9 treatments were measured across the same aspects; the sequence of treatments was varied between areas and 5 years of plantings are included seem to justify this analysis. The analysis of variance for a 3x3 factorial design is as follows:

Source	d.f.
Treatments	(8)
Site preparation	2
Planting stock	2
S.P. x P.S.	4
Error	1,341
Total	1,349

I must recognize the basis for criticizing the sampling because of non-random selection of aspect locations. However, this should primarily effect estimates of height performance rather than treatment differences. The mean heights for each treatment are presented solely as an indicator of performance (table 3). No reliability may be attached to them. I have included survival percent for comparison purposes.

Table 3.--Seedling heights and survival percents 2, 5 and 10 years after planting, Town Creek Plantation, Boise N.F.

Nursery stock:		Site preparation: None			Stripped			Stripped & furrowed		
		2-0 Spec.	2-1 Spec.	2-1 Reg.	2-0 Spec.	2-1 Spec.	2-1 Reg.	2-0 Spec.	2-1 Spec.	2-1 Reg.
Years since planted	Age	- - - - Seedling heights, feet (basis: 150 trees in each cell) - - - -								
2	4	0.48			0.61			0.54		
	5	(.60)[1/]	0.61	0.57	(0.76)	0.72	0.62	(0.67)	0.68	0.59
5	7	1.39			2.03			1.83		
	8	(1.59)	1.61	1.33	(2.31)	2.37	1.88	(2.09)	2.31	2.15
10	12	2.86			4.98			4.80		
	13	(3.10)	3.54	3.10	(5.39)	5.44	4.75	(5.20)	5.64	4.69
10-year Range		0.5-5.5	0.5-7.0	0.9-6.0	0.9-9.4	1.4-10.0	0.9-9.1	1.0-8.9	1.4-10.3	0.4-8.8
		- - Seedling survival, percent (basis: 12.7M to 21M trees per cell) - -								
2	4	52.5			87.7			87.9		
	5		72.5	51.3		99.3	83.9		97.0	91.7
5	7	31.9			74.7			79.9		
	8		42.1	23.4		85.5	71.8		93.1	82.5
5-year Range		16-42	39-59	12-35	72-88	82-91	71-76	79-80	90-95	79-83

[1/] Parenthetical values are estimates calculated by adding the periodic annual increment to the height at the end of the period.

The survival percents, as a composite for all 5 years of plantings, differ considerably from the annual percents published by Curtis and Coonrod (1960). They represent mean survival which might be anticipated from plantings over a 5-year period with comparable sites and climatic regime. Curtis and Coonrod did show significant differences in survival percent between years.

Treatment differences.--Site preparation and planting stock differences at 10 years were both highly significant ($p = .01$) (Table 4). The means, by treatments, were:

Site preparation	Mean height (feet)
None	3.18
Stripped	5.06
Stripped & furrowed	5.05
Planting stock	
2-1 Reg.	4.19
2-1 Spec.	4.88
2-0 Spec.	4.28 (4.67)[1/]

[1/] Adjusted for age difference.

The interaction term was not significant, i.e. differences were due solely to the treatments and not to interactions between treatments. Seedling heights and survival percents show similar trends (Table 3).

The 2 stripped treatments showed the best survival and the tallest seedlings in all periods. Differences between the 2 stripped treatments

Table 4.--Analysis of variance table

Source of variation	Sum of sqrs.	d.f.	Mean square	F
Site preparation	1063.4917	2.	531.7458	236.6680**
Planting stock	137.7035	2.	68.8517	30.644**
SP x PS	16.1406	4.	4.0351	1.7959 NS
ER	3013.0259	1341.	2.2468	
TT	4230.3584	1349.		

do not appear to be real. The impact of site preparation is most striking (Fig. 2).

Figure 2.--Contrast in heights between tree planted without site preparation (on left) and tree planted at same time on stripped ground (on right).

The 2-1 special stock appeared to outlive and outgrow the other two under almost all site treatments and in all periods. When mean height of 2-0 stock is adjusted for the 1-year age differential there is little difference between it and the 2-1 stock given special handling.

Unfortunately, there are several primary factors impinging on the performance of planting stock which cannot be separated. They are transportation method, time in transit, and planting method--dug hole vs. slit.

Correlation with survival.--We know height is strongly correlated with age. It also appears to be correlated with survival percent (table 3 underlined values). Logically, conditions favoring survival and establishment also favor height growth. Regression analysis (with percents transformed by the arc sin function) led to the following equation for this 3-variable relationship on these sites (Fig. 3). Growing seasons, since seed germination, is the age scale.

$$\text{Height} = -1.2348 + 0.4448(\text{Age}) - 0.1276\left(\frac{1}{(\text{Surv.Pct.})}\right)$$

Figure 3.--Regression surface showing height as related to age and survival.

Figure 2.--Contrast in heights between tree planted without site preparation (on left) and tree planted at same time on stripped ground (on right).

$$\text{Height} = -1.2348 + 0.4443(\text{Age}) - 0.1276\left(\frac{1}{(\text{Surv. Pct.})^{1.4}}\right)$$

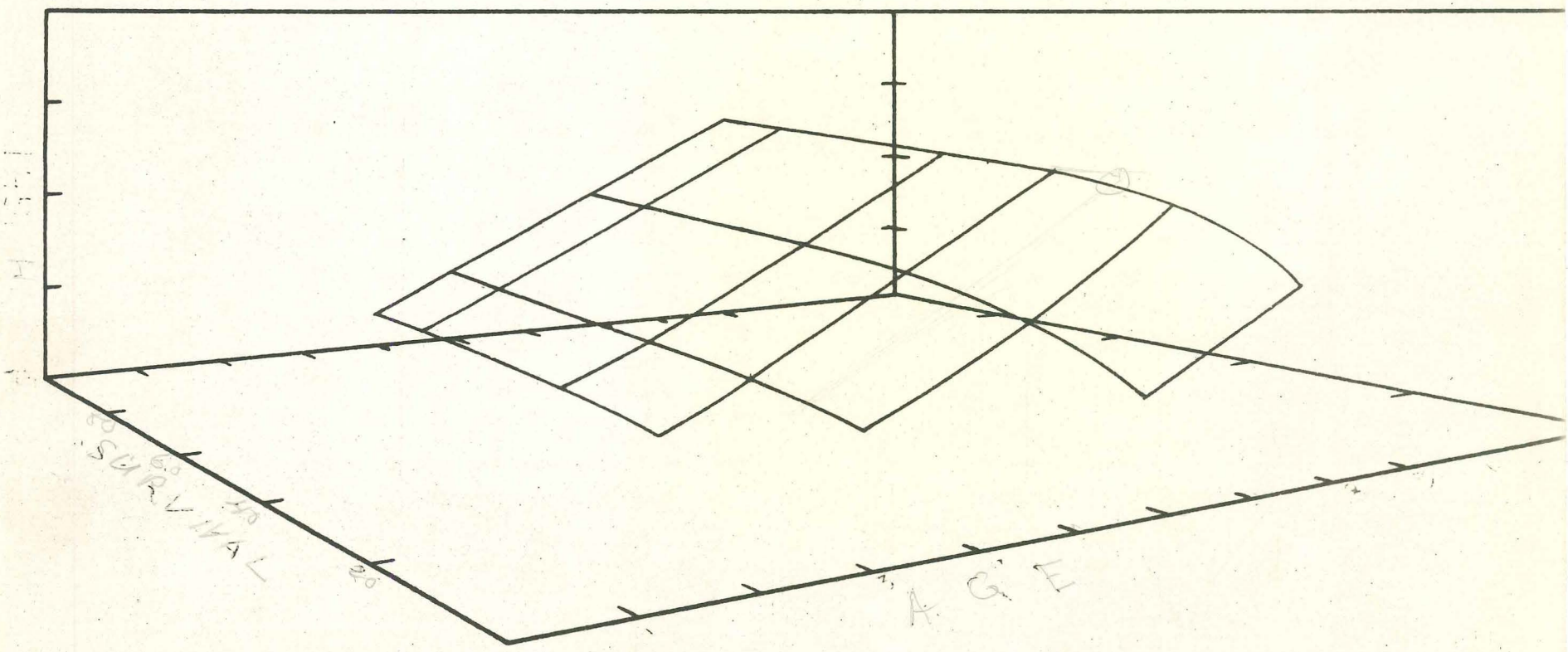

Figure 3.--Regression surface showing height related to age and survival

In this model 84 percent of the variation in height was associated with age. The combined variables, age and survival percent, accounted for 92 percent of the variation. It must be recognized that this model is only valid within the limits of data for the independent variables, i.e., Age: 4 to 8 years, Survival: 23 to 100 percent. As survival percent approaches zero the last term becomes negatively infinite--an unrealistic prediction.

The limit of the regression surface as survival approaches 100 percent is of unique interest. Logically, as the impact of mortality factors is reduced the site potential is concentrated in height growth. At 100 percent survival a mean value for height should represent the site potential for a given genotype and the associated climatic regime. The relatively flat surface above 50 percent survival suggests a rather high probability of accuracy in extrapolating the limit from a range of survival values somewhat less than 100 percent, at least for juvenile stems.

A third and fourth survival and height measurement would help substantiate the hypothesis. A designed test should add even more conclusive evidence.

Such a standard for height growth could have considerable value in estimating the effects of other treatments, such as fertilization and pruning. The standard could provide the base against which management actions may be gauged.

Projecting the specific treatment - survival curve on the surface, and comparing it with age-spacing standards, some indication of the timing and magnitude of thinning operations could be derived. (Fig. 4)

Figure 4.--Survival curve projected on regression surface.

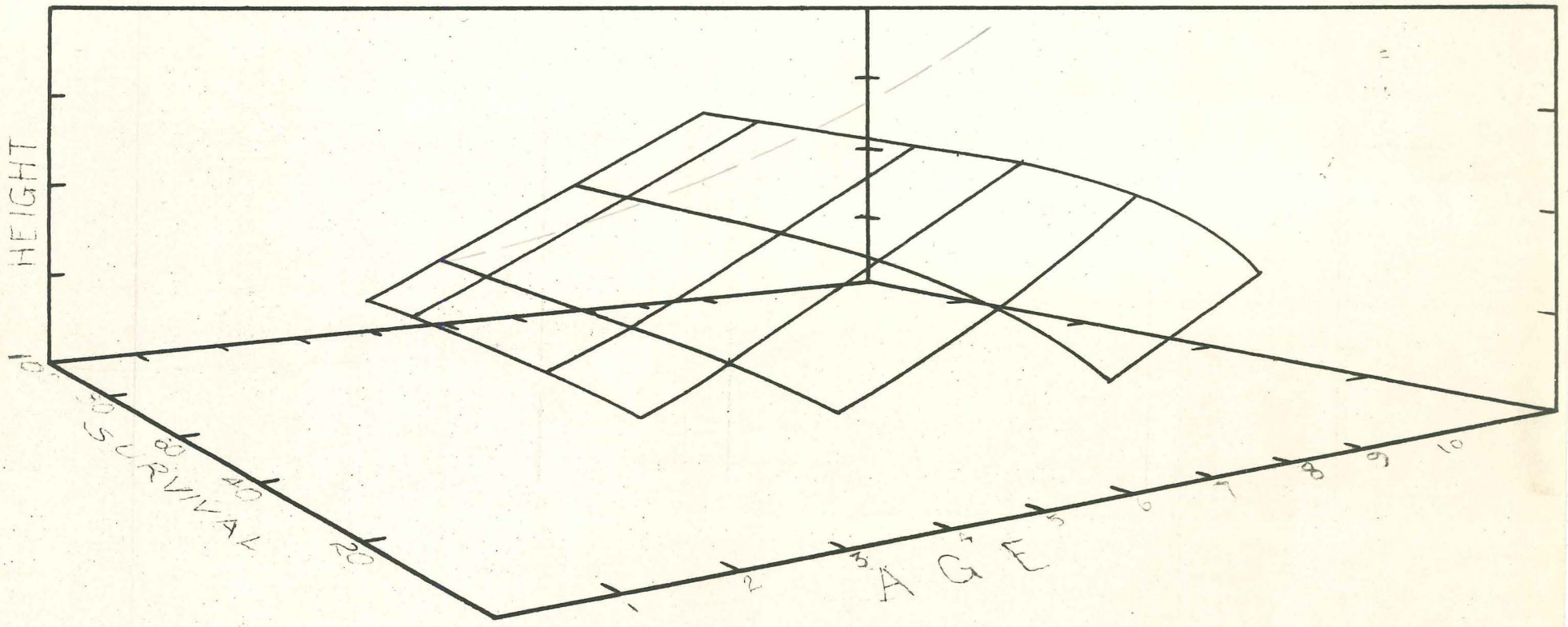

Figure 4.--Survival curve projected on regression surface.

An inherent bias may stem from the planting stock characteristics developed under different nursery soils. Russell Ryker[4/] has suggested

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[4/] Personal conversations.

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that nursery stock root form characteristics differ with nursery soil texture. Stock grown in sandy loam and stock grown in clay loam might have different root forms and perform differently when both are planted in clay loam. There has been little or no work on this aspect of regeneration.

Stock age-height relations.--Average annual height growth for the life of the seedling is the basis for comparing 2-0 and 2-1 stock (Table 5). For each site treatment the 2-1 Special stock has a definite advantage. Almost invariable it exceeds 2-0 stock in annual height growth, although the difference is not great. The 2-0 Special stock grows faster than the 2-1 Regular. The influence of stock handling and its importance are indicated by these two comparisons.

The increasing rate of height growth is quite apparent over the three growth periods (tables 5 and 6). The rate should stabilize in the next 10-year period.

Cut-bank relationship.--A secondary analysis prospect was detected halfway thru the field work in 1968. We suspected height differences between rows next to cut-banks and the outside rows. Accordingly, the sample trees in the row nearest the cut-bank were starred (*) on the field sheets for the 6 stripped treatment combinations. Both aspects in

Table 5.--Periodic annual height growth 2, 5 and 10 years after planting. Town Creek plantation, Boise N.F.

Nursery stock:		Site Preparation: None			Stripped			Stripped & furrowed		
		2-0 Spec.	2-1 Spec.	2-1 Reg.	2-0 Spec.	2-1 Spec.	2-1 Reg.	2-0 Spec.	2-1 Spec.	2-1 Reg.
Years since Planted	Seedling age	(feet)								
2	4	.120			.152			.135		
	5		.122	.114		.144	.124		.136	.118
5	7	.300			.473			.430		
	8		.333	.420		.550	.420		.543	.312
10	12	.294			.590			.594		
	13		.386	.574		.614	.574		.666	.508

Table 6.--Mean annual height growth 2, 5 and 10 years after planting. Town Creek Plantation, Boise N.F.

Nursery Stock:		Site Preparation: None			Stripped			Stripped & furrowed		
		2-0 Spec.	2-1 Spec.	2-1 Reg.	2-0 Spec.	2-1 Spec.	2-1 Reg.	2-0 Spec.	2-1 Spec.	2-1 Reg.
Years since planted	Seedling age	(feet)								
2	4	.120			.152			.135		
	5		.122	.114		.144	.124		.136	.118
5	7	.198			.290			.261		
	8		.201	.166		.296	.235		.289	.269
10	12	.238			.415			.400		
	13		.272	.238		.418	.365		.434	.361

Area 11 (1957) were sampled. The cut-banks averaged about 1½ feet (Fig. 5). A "t" test of the means of the two populations (72 & 76 trees) showed a significant different ($p = .05$). In 1968 the height of 12-year-old trees nearest the cutbanks averaged 0.365 feet greater (8.190 feet vs. 8,555 feet).

Figure 5.--Cut-bank appearance 15 years after the stripping treatment.

Ten years after planting the treatment with the tallest trees has the greatest height range:

Mean height (feet)	Height range (feet)
5.64	9.2
5.44	8.6
4.98	8.5
4.80	7.9
4.75	8.2
4.69	8.4
3.54	6.5
3.10	5.1
2.86	4.5

Apparently slow starters continued growing slowly; fast starters, fast. This suggests that with improved conditions for regeneration and establishment a broader range of inherited growth capacities survive, i.e. the impact of natural selection forces is reduced. Hopefully, at the time of thinning, management selection will replace natural selection in choosing the trees best adapted to these sites. Height growth may be only a partial indicator of a tree's adaptability and survival potential.

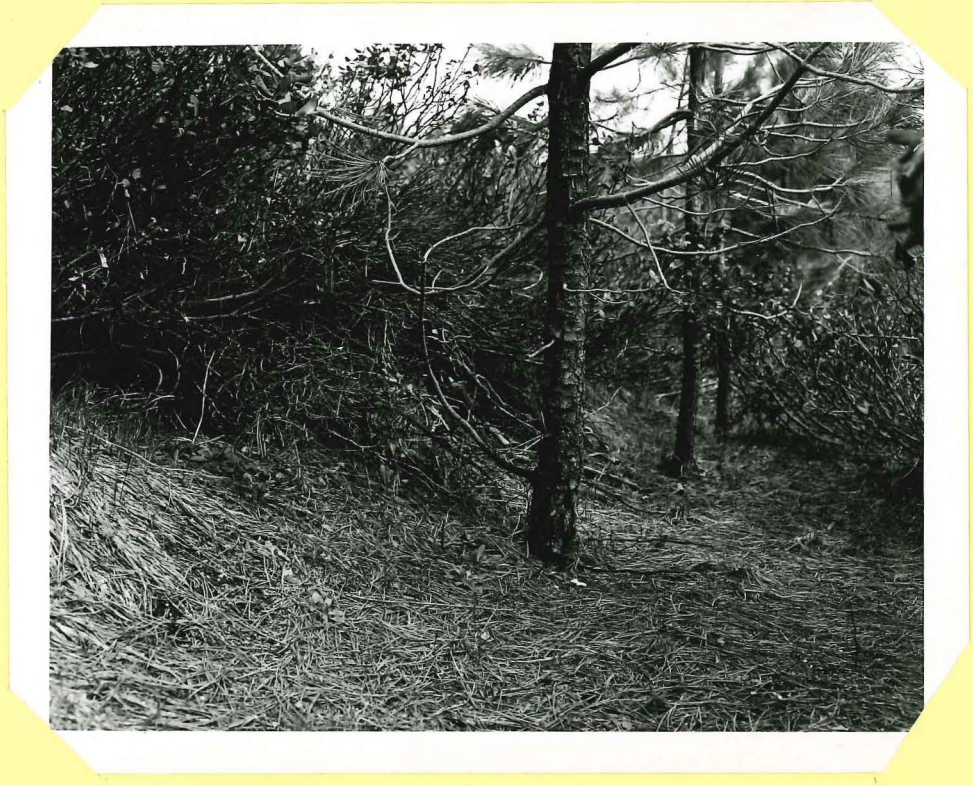

Figure 5.--Cut-bank appearance 15 years after stripping treatment.

ENVIRONMENTAL FACTORS

Uncontrolled variation in height growth is due to many factors and a multiplicity of interactions. I will briefly discuss causes for some of the variation which we observed, or for which we found evidence, while working in the plantation. This is primarily to make the observations on these factors a matter of record.

Edaphic.--Soil depth, parent material and nutritional differences were frequently apparent. A progressive increase in total height was markedly evident as some strips were followed out of a swale. This could be attributed to (a) poor drainage, or (b) varying soil depth over a massive granitic block. When transitional height pattern was found in mid-slope the occurrence of a shallow massive granitic bedrock, as described by Olson[5/] seemed probable (Fig. 6). A similar soil shallowness

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5/ Olson, O. C. A soil survey report of the Boise Basin Experimental Forest. 31 pp., illus. 1965. (Unpublished report on file (2510) at the Regional Office, Region 4, U.S.D.A. Forest Service, Ogden, Utah.)

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with reduced height growth was found on some of the ridge spurs in the areas (Olson, et al. ca. 1960).

Figure 6.--Marked height differences probably due to a shallow bedrock formation. Hall faces the first short tree in row.

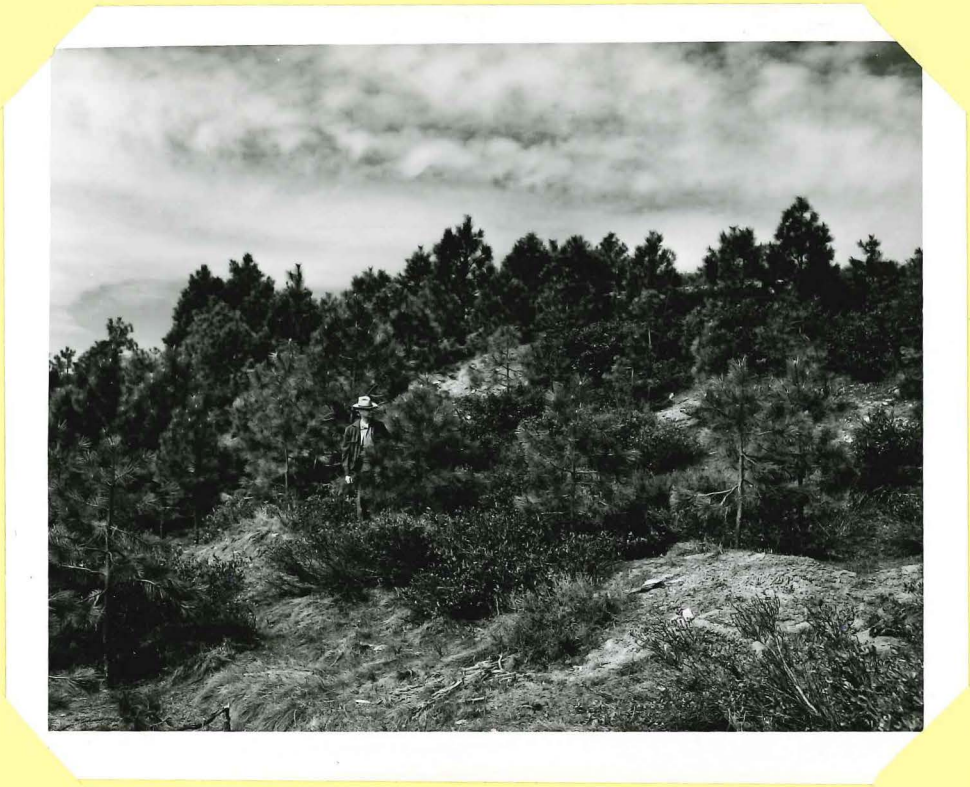

Figure 6.--Marked height differences probably due to a shallow bedrock formation. Hall faces the first short tree in row.

Soil fertility levels are also influenced by the vegetation. Nitrogen (N) is generally limiting on timberlands. Snowbrush ceanothus has been found to be an especially valuable N fixer (Woolum and Youngberg 1964), and is common at Town Creek. Two plants were able to fix a minimum of 35 ppm of available N in less than one year. Zavitkovski (1967) estimates N fixation at a rate of 20 kg./ha/yr. (18 pounds per acre) under snowbrush. At this rate it would require over 35 years to replace the N lost in logging and slash burning or from a wildfire (Zavitkovski and Newton 1968). Stripping away snowbrush, leaving roots to decompose in the soil, makes significant quantities of N available to planted seedlings and with a minimum of vegetative competition.

Some random event fertilization must also take place with the death and decomposition of animals and from their products of elimination. This could represent appreciable amounts over a period of 10 to 15 years.

Vegetation.--Vegetational differences were quite apparent thru the study area in 1968. Small natural openings 2 to 6 feet in diameter in the oft-times continuous brush cover were difficult to account for. Some seemed related to charred stumps of pitchy ponderosa pine.

Tree species were very scarce. There were a few isolated ponderosa pine (Pinus ponderosa) and Douglas-fir (Pseudotsuga menziesii ~~mertensiana~~) trees of up to 15 to 18 feet. These were probably established some years after the fire. Very rarely was a mature tree found.

Aspen (Populus tremuloides) clones occurred spotily near the stream courses or other favored sites.

Snowbrush ceanothus (Ceanothus velutinus) was the most prominent and continuous brush species--80 percent of the cover. Chokecherry (Prunus virginiana) or bitter cherry (P. emarginata) thickets were intermixed. Snowberry (Symphoricarpos alba) and elderberry (Sambucus racemosa) were scattered throughout the more continuous brush species. On some of the shallower soils and drier aspects sagebrush (Artemisia tridentata), rabbitbrush (Chrysothamnus sp.), antelope bitterbrush (Purshia tridentata), and curlleaf mountain-mahogany (Cercocarpus ledifolius) were the dominant associates.

Clumps of willow (Salix sp.) were common (10 percent of cover). The willow was an especially vigorous competitor and dominated all other species with its clump influence. Its especially vigorous sprouting, after stripping operations, suggests that no trees should be planted within 8 to 10 feet of a willow root crown.

The reinvasion and reestablishment of brush varied by species. After willow, snowbrush was especially aggressive (Fig. 7, FM 935).

Figure 7.--Reinvasion of brush after 8 years (1962). Strip behind Curtis was scraped clean in 1954.

Figure 8.--Same area as Figure 7 in 1969.

Figure 7.--Reinvasion of brush after 8 years (1962). Strip behind Curtis was scraped clean in 1954.

Figure 8.--Same area as Figure 7 in 1969.

In some areas patches of dead ceanothus attested to the ravages of the tussock moth. A grass association was showing under the brush and wholly within the influence of the dead stems.

Planting stock.--Planting stock differences both in years and between years, undoubtedly contributed much to the height variations. From 1954 to 1958 little concern for genetic strains was evident. Although stock was graded before planting, marked differences in later branching patterns visually attest to the genetic differences (Fig. 9).

Figure 9.--Needle and branch angle comparisons for two trees planted in 1954.

Seed sources undoubtedly varied annually. Practices at the Bend Nursery may have changed during the 5 years of this study and, of course climatic differences did affect seedling size and vigor. The winter of 1954-55 was dry and windy. Many seedlings were partially covered by aeolian deposits (blown soil). The soil was so dry that irrigation water had to be turned on before lifting could proceed. Needles on many trees were browned. The trees were judged dormant when lifted.[6/]

[6/] Coonrod, Melvin. Town Creek Planting Study. 1955. (Unpublished report on file at the Regional Office (R-4), U.S.D.A. Forest Service, Ogden, Utah.)

Planting stock quality varied considerably between the 1954 and 1955 plantings. In 1955 more of the 2-1 stock was culled. The average size, within the grade limits, was smaller.

Figure 9.--Needle and branch angle comparisons for two trees planted in 1954.

On the other hand, the 1955 2-0 stock was judged to be larger, more vigorous and with better root development.

Stock shipping and handling differences may also have influenced survival and height growth.

The total complex of planter training and practice, spot selection, planting depth, time until planted, planting weather and weather following, can only be noted.

Climatic.--In 1955, spring was 3 weeks later at Town Creek than in 1954. Snow depths varied from several inches to several feet at the start of planting on April 19 (planting started April 4, 1954). An additional 12 inches fell the first week. Trees were planted in puddled soil and there was some concern about compaction.[7/]

7/ Coonrod, M. p. 19.

Monthly precipitation and temperature and the 30-year averages, as recorded at Idaho City, will suggest some of the climatic variation (tables 7 & 8). Idaho City is 8 miles SSE of the plantations.

Precipitation at Idaho City in 1966 (May to October) was less than for any like period in over 35 years. The record low of 0.42 inches during the height growth period (May to July) had not been surpassed since 1931. The low precipitation and/or insect defoliation undoubtedly played a part in restricting height growth this year.

Table 7.--Monthly precipitation records, Idaho City, Idaho

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1951	3.61	3.95	2.41	1.88	1.90	1.34	.33	1.10	.01	4.92	3.58	6.31	31.34
1952	4.73	4.80	1.96	.72	1.20	1.17	.53	.02	.13	T	1.15	4.23	20.64
1953	7.34	2.91	2.42	1.68	3.75	2.21	.00	.55	.11	.40	4.77	2.77	28.91
1954	6.02	2.12	3.01	2.03	0.65	1.79	.31	.41	.21	.38	2.25	2.27	21.45
1955	1.48	1.58	2.60	4.34	1.24	1.85	.83	.00	.47	1.95	4.54	10.20	31.08
1956	4.51	3.49	1.36	1.97	3.22	1.44	.13	.03	.02	5.45	.53	4.26	26.41
1957	2.19	5.05	4.42	2.03	5.66	.14	.00	.13	.05	1.06	1.31	5.86	27.90
1958	4.34	3.72	2.00	3.49	1.28	4.57	.21	.05	.74	.24	3.26	2.59	26.49
1959	3.82	2.81	2.09	.60	3.03	.50	T	1.04	3.96	1.99	.95	1.69	22.48
1960	2.28	4.48	3.57	1.20	2.22	.00	.33	.89	.47	.91	4.19	.90	21.44
1961	1.20	2.71	3.76	1.31	1.09	.62	.04	.72	1.44	3.44	3.58	2.82	22.73
1962	1.86	2.94	2.75	1.76	3.13	.94	.17	.22	.83	3.60	2.33	1.22	21.75
1963	1.62	4.56	1.64	3.89	2.50	3.61	.00	.39	1.07	1.50	4.64	2.59	28.01
1964	5.64	0.51	3.16	1.49	.86	2.93	.37	.82	.57	.54	5.29	10.07	32.25
1965	7.57	1.27	1.22	4.14	.73	1.58	.14	1.78	1.66	.38	2.49	1.17	24.13
1966	3.69	1.07	2.37	1.12	.18	.22	.02	T	.62	.73	2.84	3.07	15.93
1967	6.62	2.21	1.18	2.08	0.87	1.83	0.05	T	1.00	--	1.85	1.73	19.42
1968	1.94	5.15	1.10	.88	1.13	1.70	T	4.89	.33	1.15	3.77		
1931-1968 Avg.	3.53	3.13	2.48	1.77	1.74	1.44	0.30	0.46	0.65	1.62	2.82	4.31	24.25

Table 8.--Monthly temperature records, Idaho City, Idaho

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1953	32.8	29.8	36.4	41.6	47.4	55.0	66.0	64.7	59.3	49.6	40.6	24.2	45.6
1954	27.0	32.6	33.8	45.1	53.5	54.7	66.7	60.5	55.5	45.9	39.9	25.0	45.0
1955	19.2	21.8	27.6	39.2	49.2	58.0	63.2	64.8	54.7	47.6	29.5	26.9	41.8
1956	26.0	21.3	32.1	44.7	53.7	56.6	64.6	61.3	55.5	--	M	26.7	44.3
1957	17.2	28.5	34.9	43.0	53.5	57.9	65.7	63.2	58.0	44.3	30.8	27.5	43.7
1958	23.6	33.1	32.9	41.1	57.6	60.1	65.4	67.8	55.7	48.8	33.9	33.1	46.1
1959	28.5	30.5	34.3	44.9	47.6	61.0	67.6	62.2	53.5	45.8	34.0	27.1	44.8
1960	22.1	24.4	34.0	44.1	49.0	60.1	70.9	62.1	59.2	46.3	34.3	26.1	44.4
1961	28.0	32.7	36.1	42.4	52.3	64.7	68.3	70.7	51.7	44.0	31.3	24.2	45.5
1962	18.6	27.9	31.2	46.4	49.6	58.7	64.4	62.3	57.4	47.2	36.7	30.7	44.3
1963	22.6	37.3	36.5	40.3	53.3	57.1	62.9	64.8	60.9	51.2	35.2	25.2	45.6
1964	15.1	23.1	29.2	40.3	49.6	57.2	67.2	62.6	53.9	49.2	32.4	26.3	42.2
1965	27.2	28.6	31.2	44.8	49.5	59.1	64.7	63.7	49.7	50.0	38.2	26.9	44.5
1966	26.1	27.6	35.7	44.0	55.0	57.7	66.0	65.9	61.0	45.2	37.1	28.4	45.8
1967	29.0	32.1	35.7	39.0	51.0	58.0	69.1	70.1	62.2	--	36.7	23.5	46.0
1968	25.1	34.9	40.2	40.5	49.1	58.7	68.3	60.8	55.7	45.2	34.5		
1931-1968 Avg.	23.3	28.2	34.4	43.7	52.2	58.5	66.7	64.8	57.2	47.8	34.1	26.9	44.8

Animals.--Animal damage was noted in the fall of 1954 after the first plantings.[8] Terminal buds were being clipped. Several rabbits were

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[8] Anonymous. Town Creek Planting Area. 1954. (Unpublished report on file at Boise National Forest, U.S.D.A. Forest Service, Boise, Idaho.)

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seen and most of the damage attributed to them.

In late 1954[9] poisoned alfalfa leaf was scattered to kill rabbits

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[9] Coonrod, op cit., p. 19.

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and oats poisoned with Decon placed at each rodent hole to kill ground squirrels. In the spring of 1955 there was no sign of rabbits. The Columbian ground squirrel was accused of cutting terminal buds in 1954 and 1955.

In 1958 rabbit and porcupine damage was again noted in the 1954 planting area.

Deer were reputed to have taken "a few terminal buds" in the spring of 1955.[10]

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[10] Coonrod, op cit., p. 19.

Domestic grazing animals were kept from the planting areas until quite recently.

Insects.--Tussock moth (Hemerocampa sp. near Vetusta) infestations were at high levels in the plantation in 1960, 1966, and 1968. Extensive

defoliation occurred (Fig. 10 - FM 930A).

Figure 10.--Tussock moth needle damage to ponderosa pine.

This tussock moth normally feeds on Ceanothus, Salix, and Prunus species. A population buildup and heavily utilization of preferred host material forced it onto the ponderosa pine. The 1960 and 1966 outbreaks were apparently controlled naturally by a polyhedral virus disease. The 1968 infestation appears to lack this natural control and may require insecticide applications in 1969 to prevent additional restrictions on tree growth.[11/]

[11/] Personal conversation with Jerry Knopf, Zone Entomologist, R-4 U.S.D.A. Forest Service.

A terminal or lateral weevil (perhaps Pissoides terminalis) was also found to be active in 1968.

IMPLICATIONS OF HEIGHT DIFFERENCES

What are the advantages of early height growth? The most apparent advantage is the high correlation with survival and establishment. A seedling with sustained vigorous height growth may be assumed to be well established. Placing its crown above neighboring vegetation makes light conditions more favorable for such intolerant species as ponderosa pine.

Figure 10.--Tussock moth needle damage to ponderosa pine.

Too, fast early growth rapidly moves the tender growing tips above the level of animal damage and perhaps into a microenvironment less hospitable to the pine tip moth (Rhyacionia sp.) and other agents.

Some questions which have been raised about tree location-height growth relations include: What is the optimum distance from a cut-bank? from brush sites? from other trees?

Site Index measurement.--Contrasting height measurements on adjacent and untreated sites (Figs. 11 and 12, FM-962, 964) implied differences in site indices, if we accept the traditional assumption that height-age relationships are constant for a given site. This apparent anomaly led me to review some of the recent literature on site index curves.

Figure 11.--Typical "no treatment" and "stripped" site preparation in 1969, 6 seasons after planting. Arrows point to trees planted in brush.

Figure 12.--Seedling planted in brush in 1954 is still alive in 1959 but badly suppressed.

The influence of density on height growth of young-growth has been examined (Lynch 1958; Husch and Lyford 1956). Intensive competition does retard height growth. A similar influence is apparent at Town Creek with seedlings subjected to brush competition.

Several authors (Arvantis, et al. 1964; Gevorkiontz 1956; Husch 1956; Mount and Gove 1952) have proposed or used age at BH rather than total age as a variable in developing site index curves. They reason that the period of initial establishment and adjustment to the site occurs before reaching this height (Husch 1956).

Figure 11.--Typical "no treatment" and "stripped" site preparation in 1959, 6 seasons after planting. Arrows point to trees planted in brush.

Figure 12.--Seedling planted in brush in 1954 is still alive in 1959 but badly suppressed.

Other authors have cited the high variation for height-age-site index relationship below 10 (Johnson 1963) or 15 (Stiell and Berry 1967) years. Contrasts between trees planted on adjacent strips at Town Creek support these contentions. After 10 years trees planted in brush were 1.6 to 2.1 feet shorter than trees planted in adjacent dozer stripped rows (Table 3). This is 57 to 66 percent of tree height on stripped sites. This range of variation on adjacent treatments could occur naturally.

The height difference promises to increase, at least for the next several years, but at a diminishing rate, i.e. the internode length, for trees in brush, is increasing toward the length for trees on stripped sites. It should be apparent that removing the years of slower growth from the age variable reduces the variation in site index estimates.

It should also be recognized that site index estimates based on trees which were free-growing during their entire life will generally be greater than estimates based on trees subjected to competition in their juvenile period--the more usual situation.

The magnitude of such an error is significant. Based on Meyer's (1938) Table 1 a 2-foot difference in site index value around S.I. 80, at 20 years, represents 4 to 5 index units--a 5 to 10 percent difference in estimates of cubic foot volume at 50 years (Meyer's, 1938, Table 6).

By excluding the years to reach b.h. from the age variable the early period of depressed height growth receives relatively less weight and reduces the amount of variation in estimates of the site productivity index. The recent practice of using age at b.h. as the variable for site evaluations appears to be well founded.

Economic comparisons.--The data from this study provide an excellent base for making economic comparisons. The addition of costs for site preparation, planting stock and planting are required. These costs were estimated as follows:[12/]

12/ Coonrod, op cit., p. 19

Site preparation:		
Stripping	$14.25 per acre	
Furrowing	4.50 per acre	
Planting stock:		
2-0	12.00 per M	
2-1	26.00 per M	
Planting:		
Prepared sites		
Slit method	25.00 per acre	(340-400 trees per man-day)
Dug-hole method	70.00 per acre	(157-182 trees per man-day)
Unprepared sites[13/]		
Slit method	40.00 per acre	
Dug-hole method	85.00 per acre	

13/ My estimates

There were 550 seedlings planted per acre.

CCA-Y (cost per 100 seedlings per acre at Y years after planting) (Hall 1967) is one index for evaluating each treatment (Table 9). Using the above costs and this index the 2-1 stock, handled conventionally and planted by the slit method at 340 to 400 trees per man-day was least expensive in each period. The high planting costs stemming from the

ble 9.--Estimated average per acre investment, survival and cost indices for 2 treatments, 1954-55, Town Creek Plantation, Boise N.F.

Nursery stock:	Site Preparation: None 2-0 Spec.	None 2-1 Spec.	None 2-1 Reg.	Stripped 2-0 Spec.	Stripped 2-1 Spec.	Stripped 2-1 Reg.	Stripped & furrowed 2-0 Spec.	Stripped & furrowed 2-1 Spec.	Stripped & furrowed 2-1 Reg.
	- - - - - - - - - - - - - - - - Dollars - - - - - - - - - - - - - - - -								
Investments:									
Initial									
Site preparation	0	0	0	14.25	14.25	14.25	18.75	18.75	18.75
Planting stock	6.60	14.30	14.30	6.60	14.30	14.30	6.60	14.30	14.30
Planting	85.00	85.00	40.00	70.00	70.00	25.00	70.00	70.00	25.00
Total	91.60	99.30	54.30	90.85	108.55	53.55	95.35	103.05	58.05
After 2 years[1/]	99.07	107.40	58.73	98.26	117.41	57.92	103.13	111.46	62.79
After 5 years[1/]	111.45	120.81	66.00	110.53	132.07	65.15	116.01	125.38	70.73
	- - - - - - - - - - - - - - - - Seedlings - - - - - - - - - - - - - - - -								
Seedling tallies:									
Initial	550	550	550	550	550	550	550	550	550
After 2 years	289	399	282	482	546	461	483	534	504
After 5 years	175	232	129	411	470	395	439	512	454
	- - - - - - - - - - - - - - - - Dollars - - - - - - - - - - - - - - - -								
CCA-Y:									
CCA-0	16.65	18.05	9.85	16.50	19.75	9.75	13.35	18.75	9.50
CCA-2	34.28	26.91	20.82	20.39	21.50	12.56	21.35	20.87	12.46
CCA-5	63.69	52.07	51.21	26.89	28.10	16.49	26.42	24.49	15.56
	- - - - - - - - - - - - - - - - Dollars - - - - - - - - - - - - - - - -								
Costs per foot of seedling height:									
After 2 years	.42	.44	.37	.33	.30	.20	.40	.31	.21
After 5 years	.46	.32	.39	.13	.12	.09	.14	.11	.07

[1/] Capitalized at 4 percent per annum.

slowness of the dug-hole method, with a production rate of 157 to 182 seedlings per day,[14] accounted for this.

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[14] Coonrod, op cit., p. 19.

Using cost per foot of seedling height, at the end of each period, there was only a slight difference between the 2-1 Regular stock on stripped and on stripped and furrowed sites--the least expensive treatments.

It is of some interest that a decision was made by the Region 4 TM staff near the end of the study for operational plantings. The decision specified stripping as the site preparation and 2-0 planting stock, carefully handled and planted by the slit method. Although this exact combination of treatments was not a part of the study, the study data generally supports the decision. The CCA-Y cost for the stripped treatment was only slightly higher than for the stripped and furrowed treatment. On a cost-per-acre basis the relationship was reversed. Inasmuch as most Forest Service reporting is on a cost-per-acre basis this part of the decision cannot be strongly questioned.

CCA-Y for "2-1 regular" stock was appreciably less than for the other two planting treatments. About 70 percent of the special treatment costs were because of the dug-hole planting method. Thus, the less expensive planting method--slit planting--applied to the least expensive planting stock--2-0--should provide the lowest CCA-Y index. This reasoning fully supports the decision.

LITERATURE CITED

Arvanitis, L. G., Linquist, J., and Palley, M. 1964. Site index curves for even-aged young-growth ponderosa pine of the west-side Sierra Nevada. Calif. Forest. & Forest Prod. No. 35, 8 pp., illus.

Curtis, James D., and Coonrod, Melvin A. 1960. The Town Creek ponderosa pine plantations. Soc. Amer. Forest. Proc. 1960: 21-25.

Gevorkiontz, S. R. 1956. Site under curves for balsam fir in the Lake States. U.S. Forest Serv. Lake States Forest Exp. Sta. Tech. Note 465.

Hall, Dale O. 1967. Broadcast seeding ponderosa pine on the Challenge Experimental Forest...a progress report. U.S.D.A. Forest Serv. Res. Note PSW-144, 4 pp., illus.

Husch, B. 1956. Use of age at d.b.h. as variable in the site index concept. J. Forest. 54: 340.

_____ and Lyford, W. H. 1956. White pine growth and soil relationship in southeastern New Hampshire. Univ. N. H. Agr. Exp. Sta. Tech. Bull. 95.

Johnson, Floyd A., and Worthington, Norman P. 1963. Procedure for developing a site index estimating system from stem analysis data. U.S.D.A. Forest Serv. Res. Pap. PNW-7, 10 pp., illus.

Lynch, Donald W. 1958. Effects of stocking on site measurement and yield of second-growth ponderosa pine in the Inland Empire. U.S. Forest Serv., Intermtn. Forest & Range Exp. Sta. Res. Pap. 56, 36 pp., illus.

Meyer, Walter H. 1938. Yield of even-aged stands of ponderosa pine. U.S.D.A. Tech. Bull. 630,59 pp., illus. (Rev. 1961).

Mount, Peter, and Gove, William. 1952. Site index for spruce-fir stands based on age at breast height and total height. Univ. Maine Forest. Dep. Tech. Note 13, 3 pp., illus.

Olson, O. C., Arnold, J. F., and Coonrod, M. A. 1960. Some tree vigor-soil relationships in the Town Creek plantation. U.S.D.A. Forest Serv., Boise National Forest, 8 pp., illus.

Stiell, W. M., and Berry, A. B. 1967. White spruce plantation growth and yield at the Petawa Forest Experiment Station. Canad. Dep. Forest. & Rural Develop. Publ. 1200, 15 pp., illus.

Woolum, A. G., II, and Youngberg, C. T. 1964. The influence of nitrogen fixation by nonleguminous woody plants on the growth of pine seedlings. J. Forest. 62: 316-321, illus.

Zavitkovski, Jerry. 1967. Snowbrush, Ceanothus velutinus Dougl., its ecology and role in forest regeneration in the Oregon Cascades. Abstr. of Ph.D. Thesis in Diss. Abst. 27B(8): 2564.

_____ and Newton, M. 1968. Ecological importance of snowbrush Ceanothus velutinus in the Oregon Cascades. Ecology 49: 1134-1145, illus.

TOWN CR. Ht. GROWTH - 1968 APPENDIX A

~~STAND TABLE~~

Deck Nbr. = 021

Tallied by: _____ Date: _____

Punched by: _____ _____

Verified by: _____ _____

Height Measurements (feet & tenths

(1)	(2)	(3)	(4)	(5)	(6)	(7)					(12)					(17)					(22)				
YEAR & MO	~~Area CMPT~~	SUB-CMPT	AREA (Ac.)	~~SP.~~	DBH	TREE CLASS 10					TREE CLASS 20					TREE CLASS 30					~~TREE CLASS 40~~				
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	1	2	3	4	5
XXXX	XX	XX	XX.XX	XX	XX.X	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	~~XXX~~	~~XXX~~	XXX	~~XXX~~	XXX
																							68		
																							67		
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																							64		
																							63		

Remarks:

Aspect = _ _ _ _

448

INT-1202 ~~424.3~~ (DOH 10/67)

APPENDIX B

DO Hall
11/18/68

TOWN CREEK HEIGHT GROWTH (DK 21)

(FS-INT 1202-448) [On modified form 1202-424.3]

Card Colum	ITEM	FORM COL.
1-3	DK. NBR. (021)	
4	Blank	
5-8	YR-MN	(1)
9	Blank	
10-11	CMPT (AREA)	(2)
12-13	SUB CMPT. (SECTION)	(3)
14	Blank	
15-16	STRIP NBR.	(5)
17	Blank.	
18-20	Ht. TREE 01	(7)
21-23	02	(8)
24-26	03	(9)
27-29	04	(10)
⋮	⋮	⋮
60-62	15	(21)
64	Blank	
65-66	YR. OF GRWTH	(23)
67	Blank	
68-71	ASPECT	(REMARKS)
72	Blank	
73-80	(1202-448)	